Life History Characteristics of Dolly Varden in the Campbell River and Puntledge River Watersheds

Submitted to:

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Summary

- In response to Dolly Varden conservation concerns, the BC Ministry of Water, Land and Air Protection (WLAP) and BC Hydro (BCH) identified a need for improved life history information of Dolly Varden populations on Vancouver Island.

- This study investigated Dolly Varden populations in 3 BCH reservoirs on Vancouver Island: Comox Lake, Campbell Lake and Upper Campbell/Buttle Lake between September 13, 2001 and June 27, 2002. Field data was collected primarily through snorkel surveys using a total of 58 snorkel surveys on 22 streams in the study area. Data loggers were used to collect water temperature information at 6 representative streams in the study area.

- Surveys found that a few gravid adults had moved into their spawning streams by mid-September. The numbers generally increased during late-September and early-October as the adults moved from the reservoirs into the streams to spawn. The counts generally peaked around mid-October as most of the spawning population appeared to have arrived at their destination, with the exception of Thelwood and Price Creeks on Buttle Lake and Rees Creek on Comox Lake, where the numbers peaked in early November.

- Peak counts are indicative of at least a minimum run size. The highest peak count of 236 spawners was observed in Thelwood Creek on October 30.

- Spawning activity varied between the streams that were surveyed, but generally occurred between mid-October and early December.

- Most of the spawning occurred in streams that were relatively cold and stable, often in low gradient reaches the headwaters or in canyon reaches. We found no indication of spawning in the lower reaches of the larger tributaries such as the Cruickshank and Elk Rivers.

- Spot checks found few redds in the operational drawdown zone of the reservoirs. Two fresh Dolly Varden redds were found in the drawdown zone at the mouth of Thelwood Creek, but the one-time counts were considered to be incomplete.

- A total of 24 sexually mature Dolly Varden were sampled from the spawning population in the Thelwood River on November 1, 2001. The spawning males had a mean length of 35 cm and the females 31 cm.

- The fecundity of 4 gravid females from Thelwood Creek ranged from 541 to 933 eggs, which was generally lower than the average fecundity of 1,000 eggs per female that was assumed for previous population estimates in the Elk River.

- An embryo development schedule was combined with the water temperature data to calculate the expected dates of fry emergence at the 6 streams where temperature data was collected. The estimated period of fry emergence in the study streams started as early as March 22 in Miller Creek and continued as late as June 30 in Thelwood Creek.

- Few juvenile Dolly Varden were observed during our snorkel surveys and little useful data regarding the life history of juvenile Dolly Varden was collected. Factors that may have contributed to this are discussed.

- Recommended studies to improve life history knowledge for Dolly Varden include improved population estimates, instream juvenile life history and a more thorough assessment of spawning in the reservoir operational zone.

1.0 Introduction

The sport angler catch of Dolly Varden (*Salvelinus malma*) on Vancouver Island has declined by 50% over the past 5 years (Reid pers. comm.). Data from the Keogh River on Vancouver Island also indicates a generally declining trend in anadromous Dolly Varden escapements and smolt production since 1987 (BCWLAP-FB-VIR 2002).

In response to Dolly Varden conservation concerns, the BC Ministry of Water, Land and Air Protection (WLAP) and BC Hydro (BCH) have identified a need for improved life history information of Dolly Varden populations on Vancouver Island. Of particular interest were the populations associated with the BCH reservoirs in the Campbell River and Puntledge River watersheds since they are potentially affected by operational changes in reservoir levels and stream flows.

MJ Lough Environmental Consultants (MJL) carried out field studies on Dolly Varden in tributary streams of reservoirs in the Campbell and Puntledge watersheds between September 13, 2001 and June 27, 2002. The study objectives were to collect information on Dolly Varden life history including:

- Timing of adult migration from the reservoirs into spawning streams
- Estimation of the number of spawning adults
- Timing and location of spawning
- Period of egg incubation and timing of fry emergence

2.0 Study Area

This study investigated Dolly Varden populations in 3 BCH reservoirs on Vancouver Island (Figure 1):

1. Comox Lake (Comox Reservoir) in the Puntledge River watershed.
2. Campbell Lake (Ladore Reservoir) in the Campbell River watershed.
3. Upper Campbell Lake/Buttle Lake (Strathcona Reservoir) in the Campbell River watershed.

Field investigations focussed on the tributary streams to these reservoirs, starting in the late summer and fall as the adults from the lake populations moved into the streams to spawn.

The Ladore and Strathcona reservoirs are not accessible to anadromous fish with the exception of those fish that are accidentally diverted into the Ladore Reservoir from BC Hydro water diversions from the Quinsam River and Salmon River (primarily coho and steelhead smolts). Populations of cutthroat trout (*Oncorhynchus clarki*), rainbow trout *(O. mykiss*) and Dolly Varden char inhabit both reservoirs (BCWLAP-FB-VIR 2002). There are no fish passage facilities at the Ladore Dam or the Strathcona Dam.

The headwaters of the Puntledge River were historically accessible to anadromous fish, but since the Comox Dam was built at the outlet of Comox Lake there are now only sporadic occurrences of anadromous adults upstream of the dam, despite the

incorporation of fish passage facilities at the dam (Hurst 1991). Consequently, waters upstream of the dam are now heavily stocked with salmon and steelhead juveniles produced from the Puntledge Hatchery. Populations of cutthroat trout, rainbow trout, kokanee (*O. nerka*) and Dolly Varden have been documented in Comox Lake (BCWLAP-FB-VIR 2002).

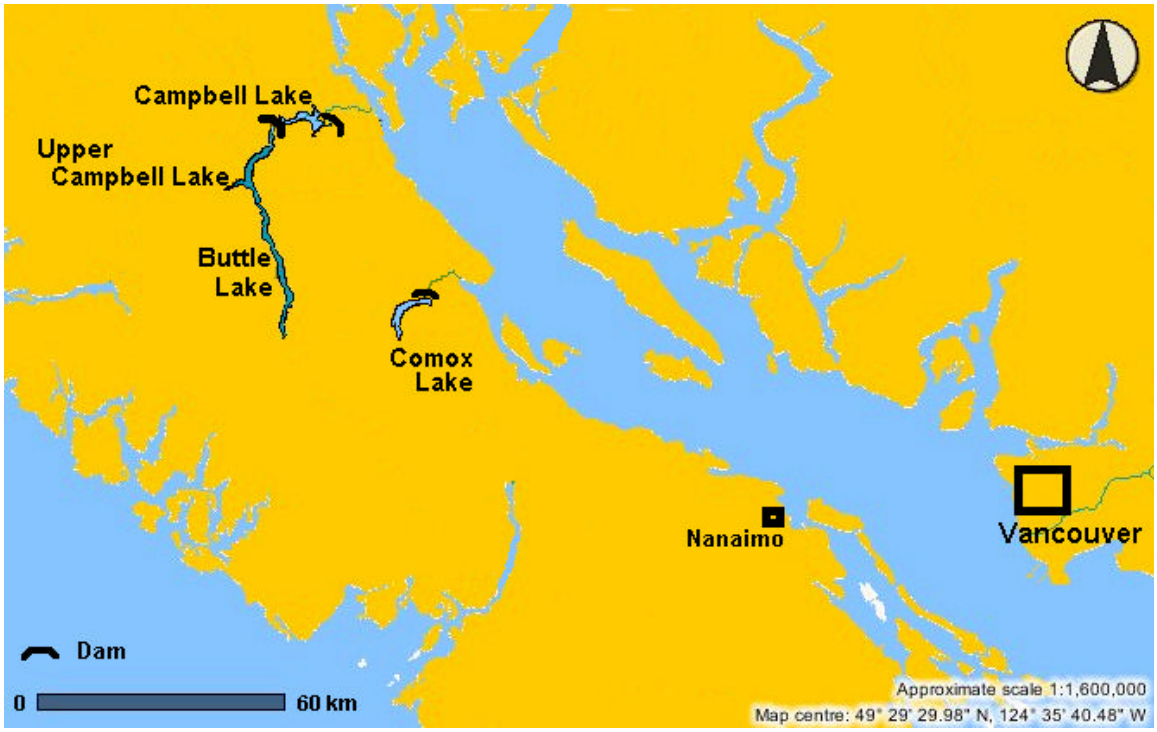

Figure 1 Location of the reservoir lakes in the Campbell and Puntledge watersheds that were included in the study

3.0 Methods

Field data from this study was collected primarily through snorkel surveys. A single crew of 2 experienced swimmers from MJL carried out most of the swims. A second crew of 2 experienced swimmers from the Fish and Wildlife Section of the BC Ministry of Water, Land and Air Protection provided additional support during the peak of spawning activity. Field observations during these surveys provided the counts and distribution of Dolly Varden as well as the time and location of their spawning.

Streams were selected for snorkel survey coverage if they were:

- a tributary of Buttle, Campbell, Upper Campbell or Comox Lakes
- reported to have a Dolly Varden population
- accessible to snorkel survey crew
- suitable for snorkel surveys (good visibility, swimable etc).

A total of 58 snorkel surveys were done on the 22 streams that were included in the study (Table 1). Due to the limited time and resources of the snorkel crew, it was not possible to survey all of the streams on a regular basis. We therefore tended to survey streams with a confirmed or suspected historical presence of adult or juvenile Dolly Varden. These streams were used as "index" or representative streams where adult Dolly Varden were monitored until the beginning of spawning activity, at which time the remaining streams in the area were quickly surveyed. In this manner some streams were only surveyed once, but at a time when the likelihood of Dolly Varden numbers and spawning activity was maximized (Figures 2 to 4).

Table 1 Streams that were included in the snorkel surveys to collect information on Dolly Varden spawning activity

Lake (BCH Reservoir)	Stream
(Lower) Campbell Lake	Fry Creek
	Greenstone Creek
	Miller Creek
	Campbell River (Strathcona Dam tailrace) *
Upper Campbell Lake	Cervus Creek *
	Drum Creek
	Elk River *
	Filberg Creek
	Tlools Creek
Buttle Lake	Henshaw
	Marblerock Creek
	Phillips Creek
	Price Creek
	Ralph River
	Thelwood River *
	Wolf River
Comox Lake	Comox Creek
	Cruickshank River
	Kweishun Creek
	Puntledge River (Forebush Lake to Willemar Lake)
	Puntledge River (Willemar Lake to Comox Lake)
	Rees Creek *

* Index streams that were monitored more frequently to provide an indication of spawning activity in neighboring streams

Elk River and Cervus Creek were used as index streams of the Upper Campbell Lake watershed. Elk River was selected because Dolly Varden were reported in previous years during previous WLAP snorkel surveys (BCWLAP-FB-VIR 2001). Cervus Creek was selected because of its accessibility and because the falls at Km 0.5 are a barrier to upstream migrants. Spawning Dolly Varden were easier to find and observe since they were limited to the lower 0.5 km of the stream below the falls. Water temperatures and flow conditions in Cervus Creek appeared to be representative of other Elk River tributaries.

The Upper Puntledge River (upstream of Comox Lake and upstream of Willemar Lake) and the Cruickshank River were surveyed because both have historical records of Dolly Varden, primarily juveniles captured during electrofishing (Griffith 1995). We selected the Cruickshank River and Rees Creek as the index streams for the Puntledge watershed, primarily because Dolly Varden adults were found in these streams early in this study and also because they were more accessible than other streams and usually had good visibility for conducting snorkel surveys.

The Thelwood River was selected as the index stream for Buttle Lake because it was relatively easy to access for the snorkel survey crew and because the historical presence of Dolly Varden had been well documented by previous WLAP snorkel surveys (BCWLAP-FB-VIR 2001).

The Campbell River (at the Strathcona Dam tailrace) was selected as the index stream for Campbell Lake primarily because Dolly Varden adults were found here early in the study. Also, it was a relatively confined area that was easily accessed by the snorkel survey crew.

3.1 Water Temperature Data

Water temperature data was collected and used to estimate the development of incubating eggs and to calculate the approximate period of fry emergence. Six Tidbit data loggers (Onset Computer Corporation, Pocasset, MA) were used to collect water temperature information at 6 representative streams in the study area (Table 2). Some of the data loggers were speculatively installed at known or suspected spawning streams during September and additional data loggers were installed during October as additional spawning areas were identified.

Table 2 Details of water temperature data loggers installed at representative streams in the study area.

Stream	Reservoir	Data Period	Location
Cervus Creek	Upper Campbell Lake	Oct 24 - Jun 27	Km 0.2
Cruickshank River	Comox Lake	Sep 30 – May 21	Km 2.0
Elk River	Upper Campbell Lake	Sep 30 – May 21	Elk River mainline crossing
Greenstone Creek	Campbell Lake	Sep 30 – May 21	Logging bridge at Km 2
Miller Creek	Campbell Lake	Sep 14 – May 10	Elk River mainline crossing
Thelwood River	Buttle Lake	Sep 13 – May 21	Km 2

3.2 Fish Capture and Biological Sampling

A 2.5 cm mesh drift-gillnet was used to collect sexually mature Dolly Varden from a group of spawning fish in the Thelwood River on November 1, 2001. The small mesh net ensured that fish were tangled instead of gilled. Captured fish were anesthetized using Alka Seltzer, then sampled for length, weight and sexual maturity. All fish were released unharmed at the capture site except for 4 females, which were retained and dissected to collect fecundity information. The females were selected so as to avoid those that appeared to be partially spawned.

4.0 Results and Discussion

4.1 Migration

On September 15th, a snorkel survey of the lower 3 km of the Cruickshank River found a relatively low abundance of only 0.7 adult Dolly Varden per km, but a snorkel survey at the mouth of the river found 3 adult Dolly Varden holding along the drop-off into the lake. A check of 2 anglers at the mouth found that all 4 of the Dolly Varden that they caught were gravid adults. These findings suggest that few adults had moved into the river by mid-September, but gravid fish were apparently holding off the mouth and a few had just started their migration into the stream to spawn.

Our snorkel surveys of other larger streams such as the Elk River, Strathcona Dam tailrace and Thelwood Creek also found that a few adult migrants had already moved into the streams by mid-September. The numbers generally increased during late-September and early-October as the adults moved from the reservoirs into the streams to spawn. The counts generally peaked around mid-October as most of the spawning population appeared to have arrived at their destination, with the exception of Thelwood and Price Creeks on Buttle Lake and Rees Creek on Comox Lake, where the numbers peaked in early November (Figure 5 and Figure 6).

We found little indication of a distinct Dolly Varden population (e.g. stunted size) in the stream sections that we surveyed that might indicate the presence of a resident fluvial population. The exceptions to this were noted in Cervus and Price Creeks where small Dolly Varden (estimated 150 mm to 200 mm) were actively trying to spawn with larger gravid females. These fish appeared to be males and we suspected these fish were most likely precocious males instead of distinct headwater population. The remaining adult migrants that we observed were remarkably similar to each other in size and physical appearance. Most were 30 to 40 cm in length, with the exception of some larger spawners in the Strathcona Dam area that were estimated to range from 50 cm to 70 cm. When they entered the streams during September-October, most adults were semi-dark with obvious spots, then became darker with more pronounced white spots and orange fin coloration as they approached spawning (Appendix 1).

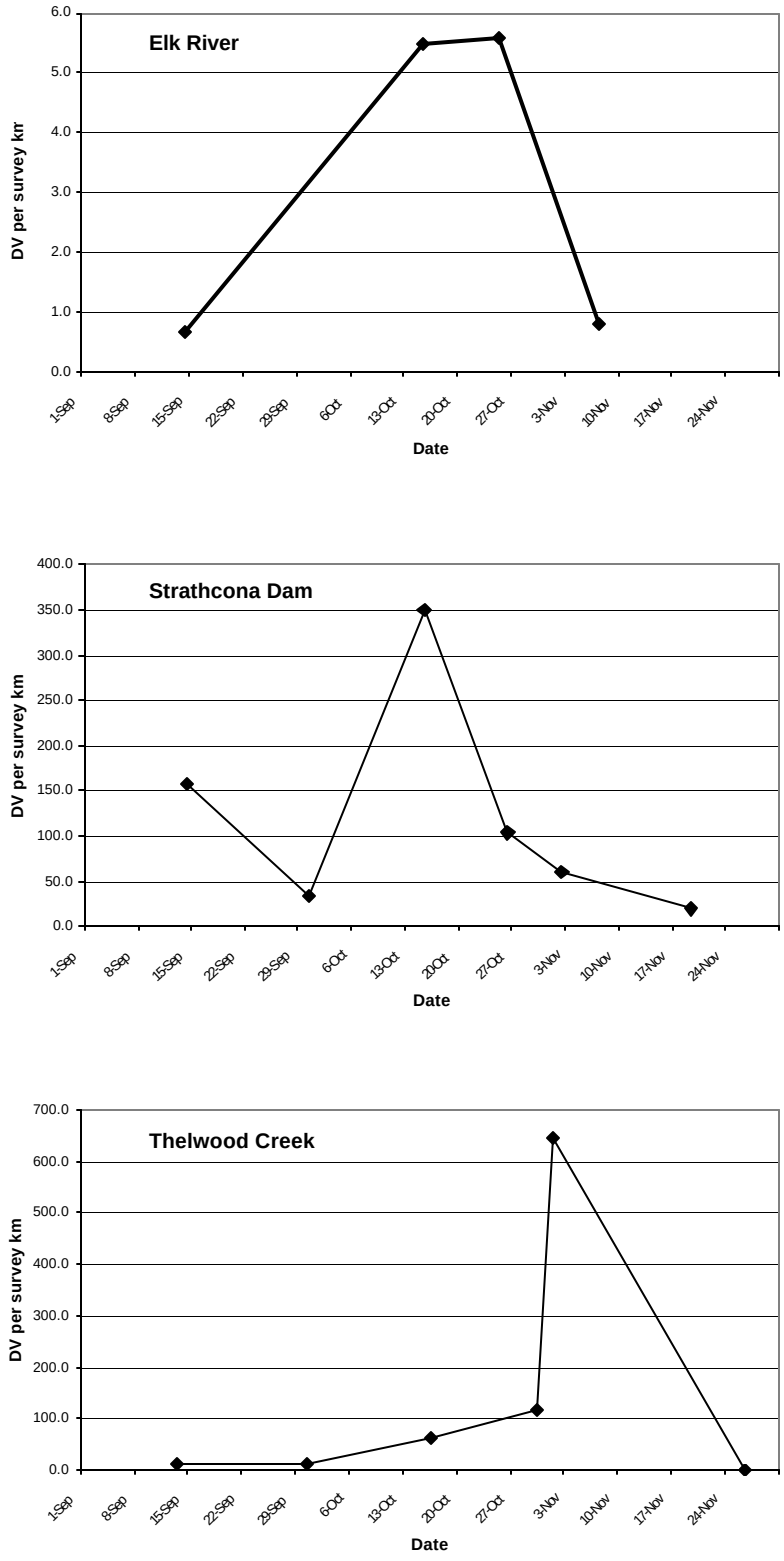

Figure 5 Abundance of Dolly Varden spawners (adults per survey km) in 3 of the larger study streams as determined from snorkel surveys, September 13-November 26, 2001

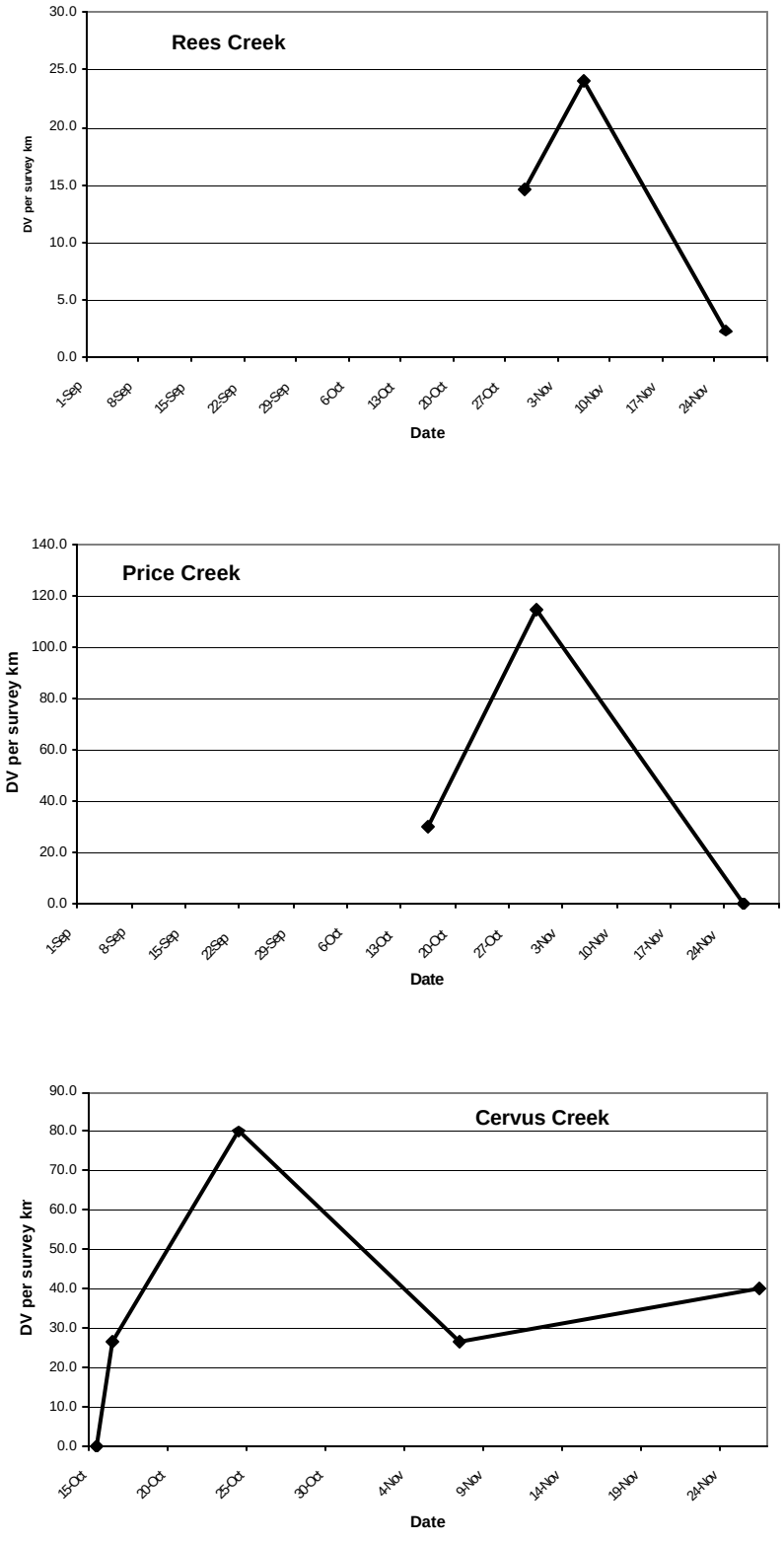

Figure 6 Abundance of Dolly Varden spawners (adults per survey km) in 3 of the small tributaries as determined from snorkel surveys, September 13-November 26, 2001

Snorkel surveys found that the adult migrants did not generally distribute themselves throughout the lower reaches of the larger streams such as the Cruickshank River and Elk River, but often gathered into aggregations of 10 to 50 fish near prospective spawning areas in the weeks prior to spawning. During this time they often remained in the mainstem, off the mouths of the smaller tributaries. As spawning time approached they entered the small streams or proceeded to the upper reaches of the mainstem.

In the Elk River, Cruickshank River and Thelwood Creek, migration into the smaller spawning tributaries coincided with increased flows at a time when water temperatures had declined to 6-7 ^{o}C. In Cervus Creek for example, no fish were found when checked during low flows on October 15th. After a night of heavy rain, a check of the same area the next day found 8 spawning Dolly Varden and 3 fresh redds.

Some of the spawners that were holding in the Thelwood mainstem (8 ^{o}C) moved into Price Creek (6 ^{o}C) and started spawning the day after the heavy rains on October 15th. Most however, remained in the Thelwood mainstem where spawning peaked nearly 2 weeks later as water temperatures eventually dropped to 6 ^{o}C. A previous study at 2 small Sayward lakes (Beavertail and Jasper) also found that Dolly Varden migrated from the lake into the small ephemeral spawning streams while flows were increasing and temperatures were declining (Lough and Hay 2001). This occurred between November 10th and Dec 13th, at a time when flows were increasing and water temperatures dropped between 8^{o}C and 4 ^{o}C. These streams were dry and inaccessible prior to the increased flows from rain events, which in 2001 did not occur until Nov 9th.

In the smaller creeks such as Cervus Creek, Rees Creek and Price Creek the highest abundance of spawners were observed during late October and early November (Figure 2). In Rees Creek, an aggregation of 42 gravid Dolly Varden held in a single pool immediately downstream of their prospective spawning site from October 29th to at least November 6th. An exception was Thelwood Creek, where most of the spawning population remained in the mainstem between Km 1 (logjam) and the barrier at Km 3 (powerhouse).

Kelts appeared to migrate back to the lakes soon after spawning, as indicated by the rapidly declining counts following peak spawning activity. The last snorkel surveys during the spawning period found that the numbers had diminished substantially by late November, although a few fish were still actively spawning in Rees Creek on November 25th and Cervus Creek on November 26th. The last of these spawners probably remained in Rees Creek until early December.

4.2 Run Size

This study was not designed to accurately enumerate the run size in the streams that were surveyed since in many cases, only a small portion of the accessible stream length was surveyed or a stream was only surveyed once during the spawning period. Nevertheless, the peak counts are indicative of at least a minimum run size. Table 3 summarizes the peak counts of Dolly Varden spawners and the total number of redds observed in the survey section of each stream.

Tredger (1979) estimated the size of the spawning population of Dolly Varden in the Elk River drainage to be approximately 2,000 fish based on his juvenile sampling data and estimates of fecundity and survival rates. However, our sampling in Thelwood Creek found generally lower fecundities than those assumed by Tredger (see Section 4.3.4), which would tend to reduce his population estimate to between 1,100 and 1,900 spawners. As Tredger points out, the generally poor knowledge of the survival rates at incubation and juvenile rearing further reduces the confidence in this type of estimate. Nevertheless, it remains the best population estimate available for the Elk River until a thorough census of the spawning population is made.

The spawning population in Thelwood Creek has been enumerated during snorkel surveys on several occasions. The highest count of 405 Dolly Varden spawners was made by BC Ministry of Environment, Lands and Parks (MELP) fisheries personnel on October 21,1998 (BCMELP-FB-VIR 2001). A peak count of 236 spawners was counted by MJL personnel during this study on Oct 30, 2001.

Table 3 Peak counts of Dolly Varden spawners and redds that were observed during snorkel surveys from September 13 to November 26, 2001

Lake	Stream	Peak Number of Spawners	Redds	Date	Comments
Campbell					
	Greenstone C	5	0	Nov 2	All kelts and no redds-suspect significant spawning further upstream
	Fry C	0	0	Nov 2	Searched for redds-none found
	Miller C	2	0	Nov 19	Spawning pair
	Strathcona Dam	105	8	Oct 15	Observed fish were 0% kelts
Upper Campbell					
	Cervus C	24	22	Oct 24	50% kelts
	Drum C	1	0	Nov 7	Searched for redds-none found
	Elk mainstem	28	12	Oct 25	Observed fish were 0% kelts
	Tlools C	14	9	Oct 24	Active spawning
Buttle					
	Henshaw C	6	6	Nov 1	Active spawning
	Marblerock C	2	0	Nov 3	Suspect spawning further upstream
	Phillips C	24	4	Nov 3	Observed fish were 10% kelts
	Price C	46	14	Oct 30	Active spawning
	Ralph R	8	3	Oct 30	Active spawning
	Shepherd C	6	2	Oct 30	Active spawning
	Thelwood C	236	73	Oct 30	Observed fish were 30% kelts
	Wolf R	0	0	Nov 3	Searched for redds-none found
Comox					
	Comox C	0	0	Oct 29	Suspect spawning further upstream
	Cruickshank R	5	1	Oct 29	Suspect spawning further upstream
	Rees C	72	78	Nov 6	Observed fish were 25% kelts
	Upper Puntledge R	0	0		Suspect spawning upstream of Forebush Lake

4.3 Spawning

4.3.1 Timing

Spawning activity varied between the streams that were surveyed, but generally occurred between mid-October and early December. Observations of spawning activity and estimated period of spawning are summarized in Table 4.

Table 4 Summary of spawning activity, as observed during snorkel surveys between September 13 and Nov 26, 2001

Reservoir	Stream	Estimated Spawning Period	Comments
Campbell Lake	Greenstone Creek	Late October to early November	5 kelts and no redds observed in lower 1.8 km on Nov 2 suggest spawning further upstream
	Miller Creek	Late November	Only 1 gravid pair observed on Nov 19
	Strathcona Dam	mid-October to mid-November	Peak adult count and some redds on Oct 15, but active spawning continued to Oct 26. Some gravid females still in area Nov 2
Upper Campbell Lake	Elk River	mid-October to mid-November	Peak adult counts Oct 15 to Oct 28. Redds observed Oct 28 and a few spawners still observed Nov 7
	Cervus Creek	mid-October to late November	First redd Oct 16. Peak spawning last week of October. Last gravid female with 11 males observed on Nov 26
	Tlools Creek	Late October	14 adults actively spawning Oct 25, but not checked again
Buttle Lake	Henshaw Creek	Late October Early-November	7 spawners and 4 redds observed Nov 1
	Phillips Creek	Late-October to early November	24 spawners and 4 redds observed Nov 3
	Price Creek	mid-October to mid-November	First redd Oct 16. Peak spawning Oct 30. No fish in stream Nov 26
	Ralph River	Late October to early November	8 gravid, but un-spawned adults observed Oct 30
	Shepherd Creek	Late October to early November	6 gravid, but un-spawned adults observed Oct 30
	Thelwood Creek	mid-October to mid-November	First redds Oct 16. Peak spawning first week November. No fish in stream Nov 26.
Comox Lake	Cruickshank River	Unknown	Unable to confirm spawning in lower reaches of mainstem. Adult migrants and first kelt Oct 6 suggest spawning in mainstem headwaters or tributaries
	Rees Creek	Late October to early December	First redds observed Oct 29. Peak spawning early to mid-November. A total of 7 spawners (mix of kelts and un-spawned fish) still remaining on Nov 25.

4.3.2 Spawning Habitat

Most of the spawning occurred in streams that were relatively cold (often with alpine headwaters) and relatively stable. Spawning areas were often in low gradient reaches the headwaters or in canyon reaches, both which have relatively stable channels. We found no indication of spawning in the lower reaches of the larger tributaries such as the Cruickshank and Elk Rivers, where the redds would be subject to destructive channel scour during extreme winter floods (Appendix 4).

Small numbers of Dolly Varden redds (usually 2 or 3 redds) have been reported at the lake outlets of Whymper Lake (Michalski, pers. comm.), Beavertail Lake, Jasper Lake (Lough and Hay 2001) and Crest Lake (Lough and Hay, in prep.). During this study however, we found no indication of spawning in the outlet streams from low-elevation lakes, such as the Upper Puntledge River, Miller Creek and Fry Creek. Despite the fact that these areas are heavily used in the spring by spawning cutthroat and rainbow trout, they do not appear to be heavily used by Dolly Varden. These locations have cold temperatures during the fall and winter, along with the advantage of relatively stable winter flows, but they may also have the disadvantage of warming too quickly in the spring. Fish culture experience has found that the survival of emerging Dolly Varden fry declines when water temperatures exceed 4 or 5 ^{o}C (Crawley, pers. comm.).

Substantial Dolly Varden spawning occurred at the Strathcona Dam tailrace which is technically a lake outlet, but in this case the deepwater intake in Upper Campbell Lake may result in springtime water temperatures that are suitably low. A previous study also found spawning at the outlet of Beavertail Lake and Jasper Lakes, but in these cases there were few alternatives due to the ephemeral nature of all other tributaries (Lough and Hay 2001).

Spawning Dolly Varden were found in a wide variety of stream gradients. The highest spawning densities were found in generally low-gradient (1% to 3%) of Thelwood Creek, Rees Creek, Price Creek, Cervus Creek and the Upper Elk River. Spawning was also observed in higher gradient (5% to 15%), canyon reaches such as the lower kilometer of Tlools Creek, Phillips Creek, Henshaw Creek, Shepherd Creek and Ralph River. However, even though the overall reach gradient was high, the step-pool channel morphology was stable and often afforded well-protected patches of spawning gravel among large boulders in the deep canyon pools. These characteristics combine to minimize the scouring impact of large winter floods (Appendix 1).

4.3.3 Spawning in Reservoir Drawdown Zones

A previous study of cutthroat trout spawning habitat found substantial, sometimes heavy spawning in the drawdown zones of the Ladore and Strathcona Reservoirs (Lough and Hay, 2000). Spot checks of some of these same areas during Dolly Varden spawning in 2001 found few redds in comparison, despite the fact that the Strathcona Reservoir was low with an abundance of spawning gravel available in the operational drawdown zone. Two fresh Dolly Varden redds were found in the drawdown zone at the mouth of Thelwood Creek, (approximately 200 m and 400 m upstream of the concrete bridge) on October 16. This observation was well before the peak spawning period, and additional spawning may have occurred during the following weeks. Survey crews were unable to re-visit the site.

4.3.4 Size and Fecundity of Spawners

A total of 24 sexually mature Dolly Varden were sampled from the spawning population in the Thelwood River on November 1, 2001. The spawning males were found to be larger (35.4 cm) than their female counterparts (Table 5 and Figure 7). The length-weight relationship is described in Figure 8.

Table 5 Fork lengths of spawning Dolly Varden sampled from the Thelwood River on November 1, 2001

	Sample Size	Fork Length Range	Fork Length Mean (Standard Deviation)
Males	8	31 cm - 40 cm	35.4 cm (3.2)
Females	16	28 cm – 34 cm	30.9 cm (1.5)

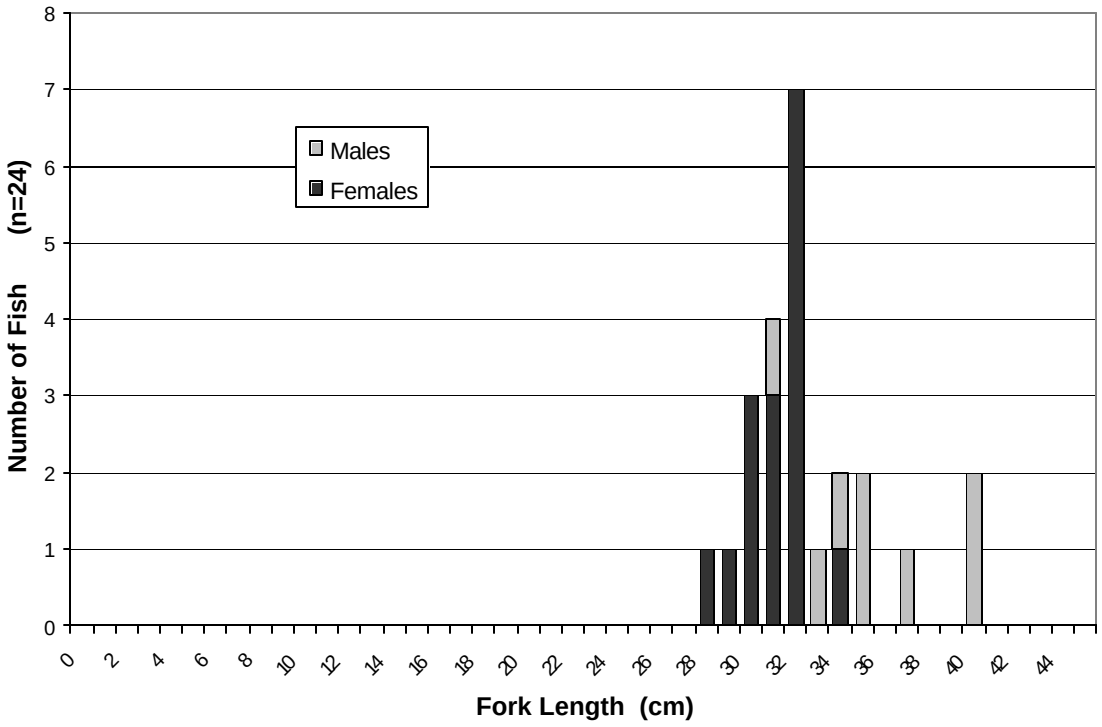

Figure 7 Length frequency distribution of spawning Dolly Varden sampled from the Thelwood River on November 1, 2001

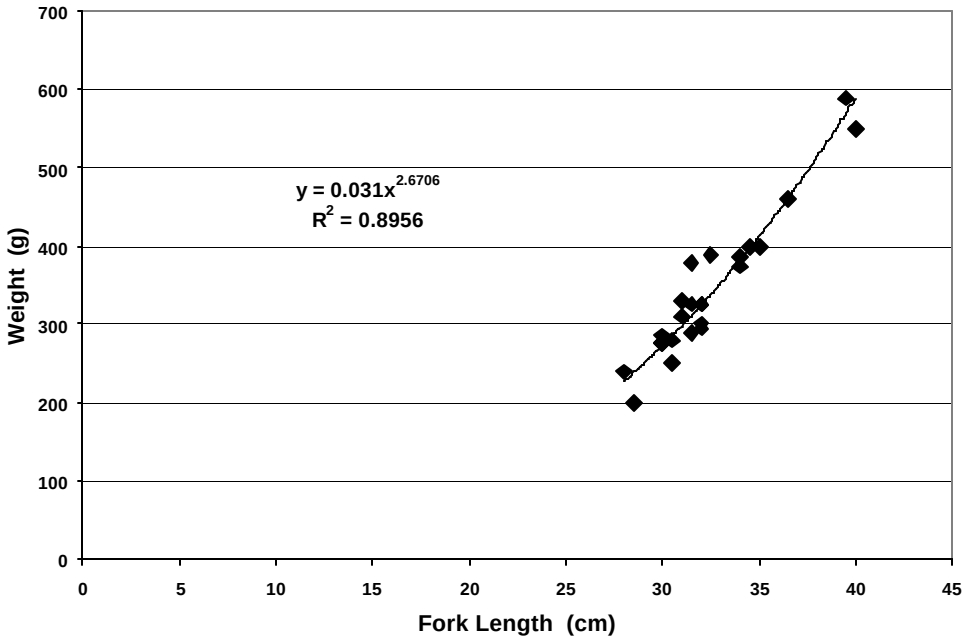

Figure 8 Length-weight relationship of spawning Dolly Varden sampled from the Thelwood River on November 1, 2001

The fecundity of 4 gravid females from Thelwood Creek ranged from 541 to 933 eggs (Figure 9), which was generally lower than the average fecundity of 1,000 eggs per female that was assumed by Tredger (1979) for his population estimates in the Elk River.

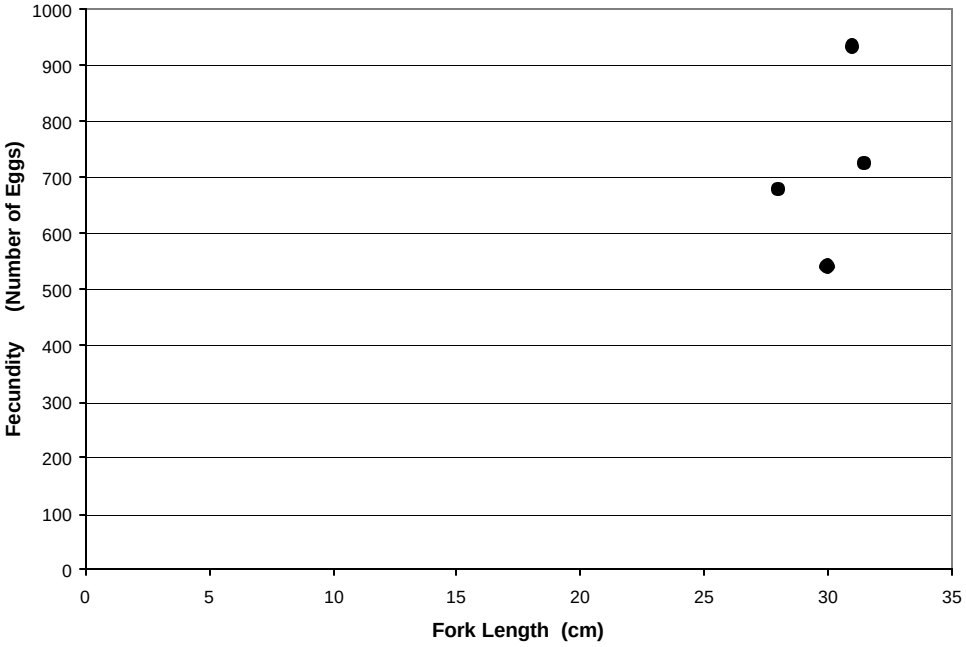

Figure 9 Fecundity of 4 female Dolly Varden spawners sampled from the Thelwood River on November 1, 2001

4.4 Egg Incubation and Fry Emergence

Three Dolly Varden redds that were known to be less than 8 days old were marked during the peak of spawning activity (October 24th) in Cervus Creek on so that they could be monitored during the incubation period. A water temperature data logger was installed at the site on the same day. These redds were then re-visited twice during the incubation period and carefully inspected to determine the stage of embryo development. The field observations were then compared to the predicted development as determined from fish culture experience for bull trout *(Salvelinus confluentus)* at Kootenay Trout Hatchery (Crawley, pers. comm.).

Field observations of embryo development at the 3 monitored redds generally agreed with the predicted schedule, although fry emergence appears to have occurred slightly ahead of the predicted date (Table 6). The differences are minor and could possibly be explained by the inability to confirm the exact date of egg fertilization.

The predicted embryo development schedule (Table 6) was then combined with the water temperature data at Cervus Creek to calculate the expected dates of fry emergence for the earliest (Oct 16) to the latest (Nov 26) spawners in Cervus Creek (Figure 10).

Table 6 Comparison of predicted embryo development of cultured bull trout with observed development at Dolly Varden redds in Cervus Creek (Elk River) during 2001-2002

Date	ATU's [1]	Predicted embryo development [2]	Observed embryo development at Dolly Varden redds in Cervus Creek
Oct 24	0	fertilization	fertilization
Dec 1 - Jan 31	200-240	eyed egg	--
Feb 18 – Mar 12	450-500	hatch	--
Mar 15	505		-Eggs have hatched. Alevin appear to be newly hatched with large yolk sacs. -Nearby redds contain a mix of eggs and alevin)
May 5	683		Marked redds are empty and emergence appears to be complete (note: redds nearby from later spawners still contain alevin)
May 9	700	emergence	--
May 20	750	fry actively feeding	--

1. Accumulated Thermal Units : accumulated mean daily water temperatures (^{o}C)
2. From Kootenay Hatchery bull trout

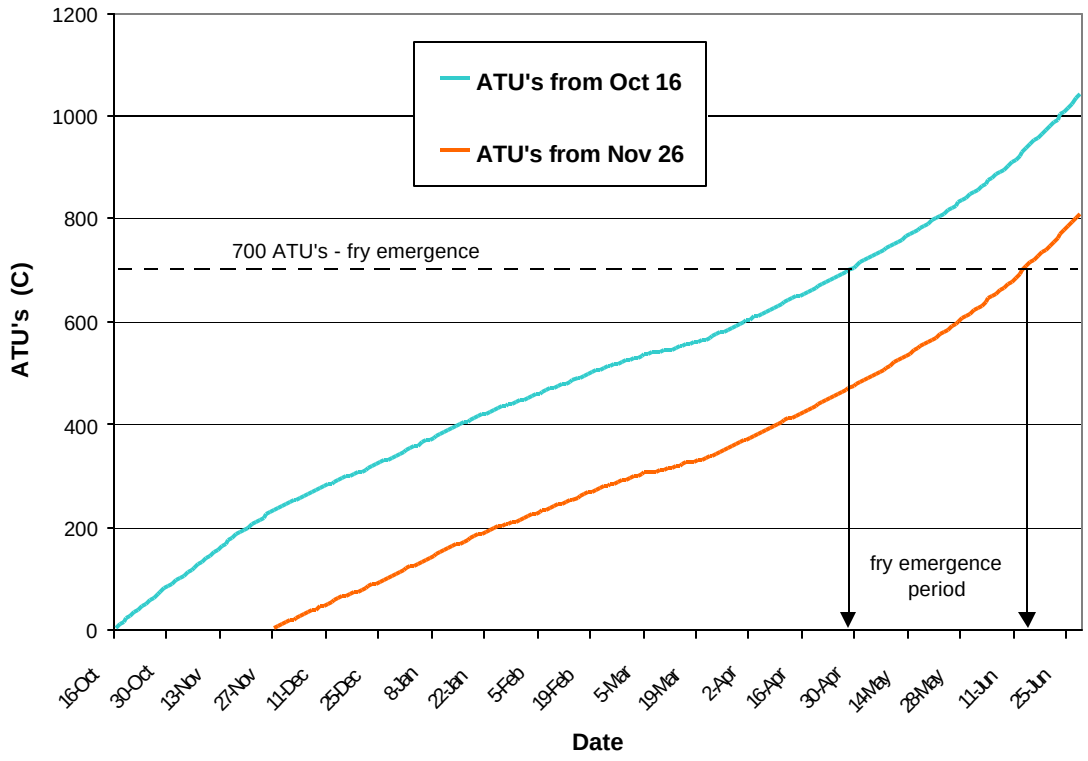

Figure 10 Temperature data from Cervus Creek was used to calculate the period emergence for Dolly Varden fry produced by the earliest (Oct 16, 2001) to the latest (Nov 26, 2001) spawners in Cervus Creek

Similar plots were made for the remaining 5 study streams where data loggers were installed (Appendix 3). In most of these streams the limits of the early and late spawning period were not actually observed and were estimated using the best available information (condition of spawners, behavior in other streams etc.). The estimated period of fry emergence (using ATU's) in the study streams started as early as March 22 in Miller Creek and continued as late as June 30 in Thelwood Creek (Table 7).

Table 7 Calculated period of Dolly Varden fry emergence using water temperature data collected at each stream during the incubation period

Stream	Emergence Period (2002)
Cervus Creek	April 28 to June 13
Cruickshank River	March 25 to May 20
Elk River	April 24 to June 10
Greenstone Creek	May 26 to June 24
Miller Creek	March 22 to May 6
Thelwood Creek	May 22 to June 30

4.5 Juveniles

Previous studies in the Puntledge and Campbell watersheds have documented a rearing population of Dolly Varden juveniles in the Cruickshank and Elk Rivers during the summer months (Griffith 1995, Tredger 1979 and Caw 1977). However, very few juvenile Dolly Varden were observed during our snorkel surveys and little useful data regarding the life history of juvenile Dolly Varden was collected. Factors that may have contributed to the low number of juvenile observations include:

- Most snorkel observations were made during the colder months of the year, often in water temperatures below 6 ^{o}C. At this temperature visual observations of juvenile salmonids are often reduced because they are less active and move into the cover of winter habitat.
- Juvenile Dolly Varden are shy, cryptic and tend to remain in or near the substrate (Appendix 1). This makes them more difficult to spot than trout for example, which are generally brighter and feeding off the bottom in the water column. Dolly Varden fry in particular, were rarely observed even though some snorkel observations were made near redds during the peak of fry emergence. Closer inspections near redd sites eventually exposed only a few newly emerged fry that were well concealed in the cobble and gravel substrate. The lack of fry observations during the day suggests that newly emerged fry may move downstream to the lake at night, soon after emergence. Night snorkel surveys could possibly provide more information in this regard.

Tredger (1979) analyzed scales of Dolly Varden sampled from Upper Campbell Lake and concluded that 50% of the adults had entered the lake as fry, 25% as 1 year olds and 25% as 2 year olds. However, his in-stream sampling during the late summer found only 0+ and 1+ juveniles, suggesting that the 2+ parr apparently moved downstream into the lake sometime prior to the summer months.

5.0 Recommendations

The following areas of study would improve the level of knowledge regarding Dolly Varden life history:

5.1 Population Estimates

Information collected during this study was useful for comparing relative abundance (number of fish/km) but was less useful as accurate census data. Snorkel surveys remain as an effective method for collecting this data, but the surveys of a spawning population should be repeated more often during the spawning period so that peak counts and stream residency information are determined. Fish counting fences are a less attractive option in most of the streams due to the typical problems with trying to maintain an operational fence during the volatile months of October and November.

Census data collected at representative streams at yearly or multi-year intervals would provide long-term population trend data. Little, if any long-term trend data is presently available for Dolly Varden populations in the study area or on Vancouver Island.

Representative or index streams that might be suitable for this purpose include known spawning populations such as Thelwood, Cervus or Rees Creeks and Strathcona Dam.

The level of knowledge could also be improved in streams that are known to have a spawning population but not enumerated. Some of these streams could have substantial numbers of spawners, but could not be thoroughly surveyed in this overview study. A one-time census would provide more information in this regard. Such streams include:

- Tlools Creek
- Greenstone Creek
- Phillips Creek
- Erick Creek

5.2 Instream juvenile life history

The knowledge of juvenile instream life history, including survival rates is generally poor but is required to better understand the factors that influence Dolly Varden populations and their habitat. This involves juvenile sampling, age and growth studies and juvenile population assessments similar to the studies by Tredger (1979) and Griffith (1995). Studies would be most effective if they focussed on streams with known spawning populations.

5.3 Spawning in the drawdown

Dolly Varden are presently blue-listed in BC, indicating that they are at risk, sensitive to human activities or natural events, but not endangered or threatened (BCSRM-CDC 2002). It may be prudent to clearly understand issues that might have negative influence on the population. One such factor was identified during this study when 2 Dolly Varden redds were noted in the operational zone of the Strathcona Reservoir. The number of redds is relatively low, but the count is considered to be incomplete since it was made prior to the peak spawning period.

Information could be improved by inspecting potential spawning areas weekly during the peak spawning weeks between mid-October to mid-November. Potential spawning areas include the mouth of Thelwood Creek, Ralph River, Elk River and Cruickshank River.

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7.0 Personal Communications

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Jenssen JT. Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC.

Michalski T. BC Ministry of Water, Land and Air Protection, Fish and Wildlife Science and Allocation Section, 2080 Labieux Road, Nanaimo, BC.

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Appendix 1 Photographs

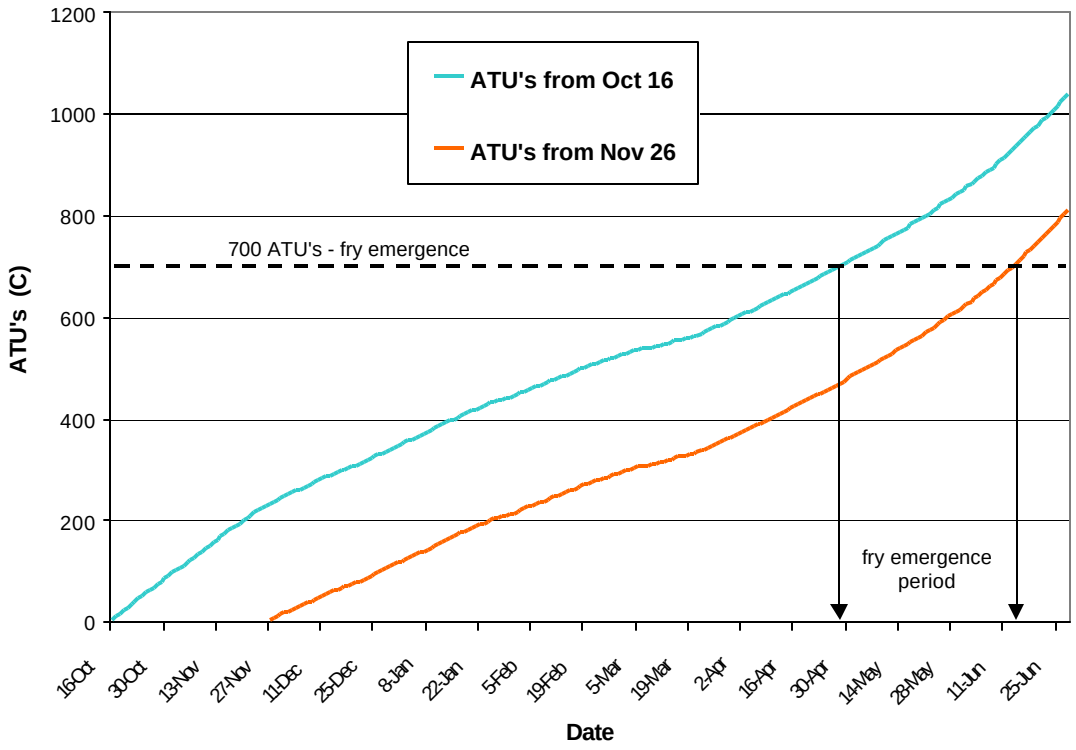
Appendix 2 Details of Snorkel Survey Coverage

Appendix 2 Details of dates and snorkel survey coverage for Dolly Varden observations

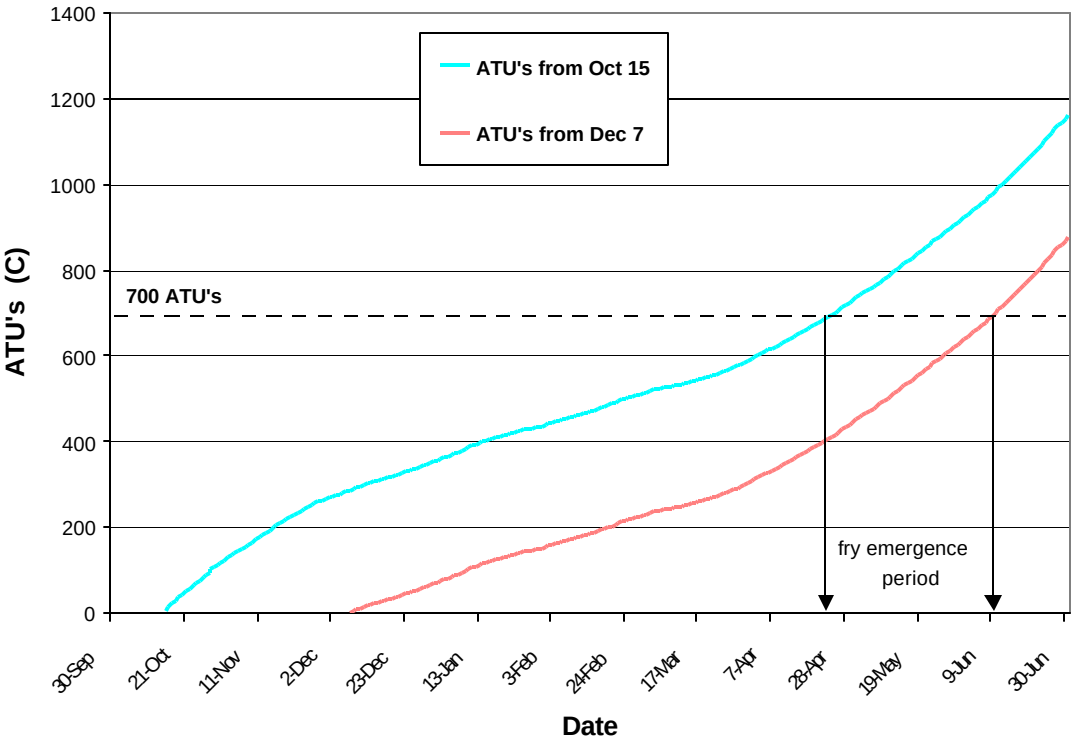
Stream	Drainage	Survey Dates	Section Surveyed	Comments
Cervus C	U Campbell L	01/10/15	Falls to mouth	
		01/10/16	Falls to mouth	
		01/10/24	Falls to mouth	
		01/11/07	Falls to mouth	
		01/11/26	Falls to mouth	
		02/03/15	Km 0.2	Redd inspection
		02/05/21	Km 0.2	Redd inspection
Comox C	Comox L	01/09/15	Km 0.8 to mouth	
		01/10/06	Km 0.8 to mouth	
		01/10/17	Km 2.0 to mouth	
		01/10/29	Km 2.0 to mouth	
Cruickshank R	Comox L	01/09/15	Comox C to mouth	
		01/10/06	Comox C to mouth	
		01/10/17	Comox C to mouth	
		01/10/29	Comox C to mouth	
		01/11/06	Km 8.0 to Km 5.5	
Drum C	U Campbell L	01/11/07	Km 0.2 to mouth	
Elk R	U Campbell L	01/09/14	Km 8.0 to Km 6.0	
		01/10/15	Km 8.0 to Km 4.5	
		01/10/24	Km 1.2 to Km 0.4	
		01/10/25	Km 12 to Km 6.5	
		01/11/07	Km 12 to Km 6.5	
Filberg C	U Campbell L	01/10/24	Km 1.0 to mouth	
Fry C	Campbell L	01/11/02	Whymper L to Fry L	
Greenstone C	Campbell L	01/11/02	Km 1.5 to mouth	
Henshaw C	Buttle L	01/11/01	Km 1.0 to mouth	
Kweishun C	Comox L	01/11/06	Km 0.1 to mouth	
Marblerock C	Buttle L	01/11/03	Km 1.0 to mouth	
Miller C	Campbell L	01/09/14	Km 0.7 to mouth	
		01/10/26	Km 0.7 to Km 0.5	
		01/11/19	Km 0.7 to mouth	
Phillips C	Buttle L	01/11/03	Km 1.0 to mouth	
Price C	Buttle L	01/10/16	Km 0.4 to mouth	
		01/10/30	Km 0.4 to mouth	
		01/11/26	Km 0.3 to mouth	
Ralph R	Buttle L	01/10/30	Km 0.8 to mouth	
Rees C	Comox L	01/10/29	Km 4.4 to Km 0.25	
		01/11/06	Km 4.4 to mouth	
		01/11/25	Km 4.4 to mouth	
Strathcona Dam	Campbell L	01/09/14	Dam to island	
		01/09/30	Dam to island	
		01/10/15	Dam to island	
		01/10/26	Dam to island	
		01/11/02	Dam to island	
		01/11/19	Dam to island	
Thelwood R	Buttle L	01/09/13	Powerhouse to logjam	
		01/09/30	Powerhouse to logjam	
		01/10/16	Powerhouse to mouth	
		01/10/30	Powerhouse to logjam	
		01/11/01	Powerhouse to logjam	
		01/11/26	Powerhouse to logjam	
Tlools C	U Campbell L	01/10/24	Km 1.0 to mouth	
U Puntledge R	Comox L	01/09/21	Forebush L to Willemar L	
		01/09/21	Willimar L to Comox L	
		01/10/06	Willimar L to Comox L	
		01/10/23	Forebush L to Willemar L	
		01/10/23	Willimar L to Comox L	
Wolf R	Buttle L	01/11/03	Falls to lake (0.5 km)	

Appendix 3

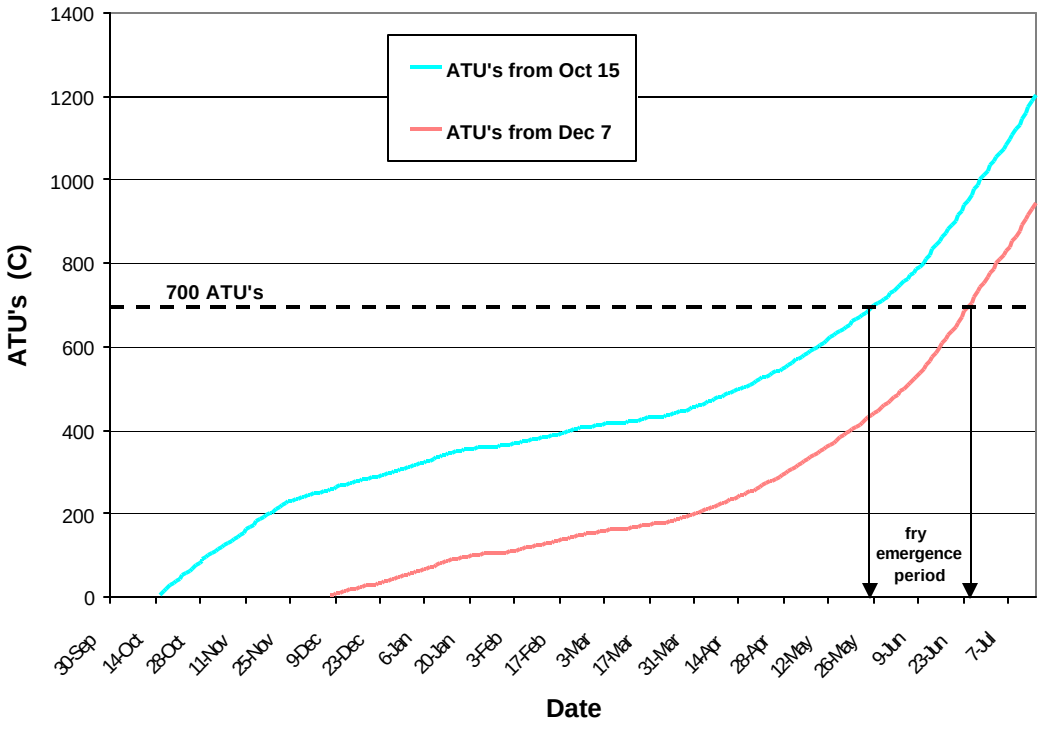
Accumulated Thermal Units (ATU's) in study streams, and estimated period of fry emergence



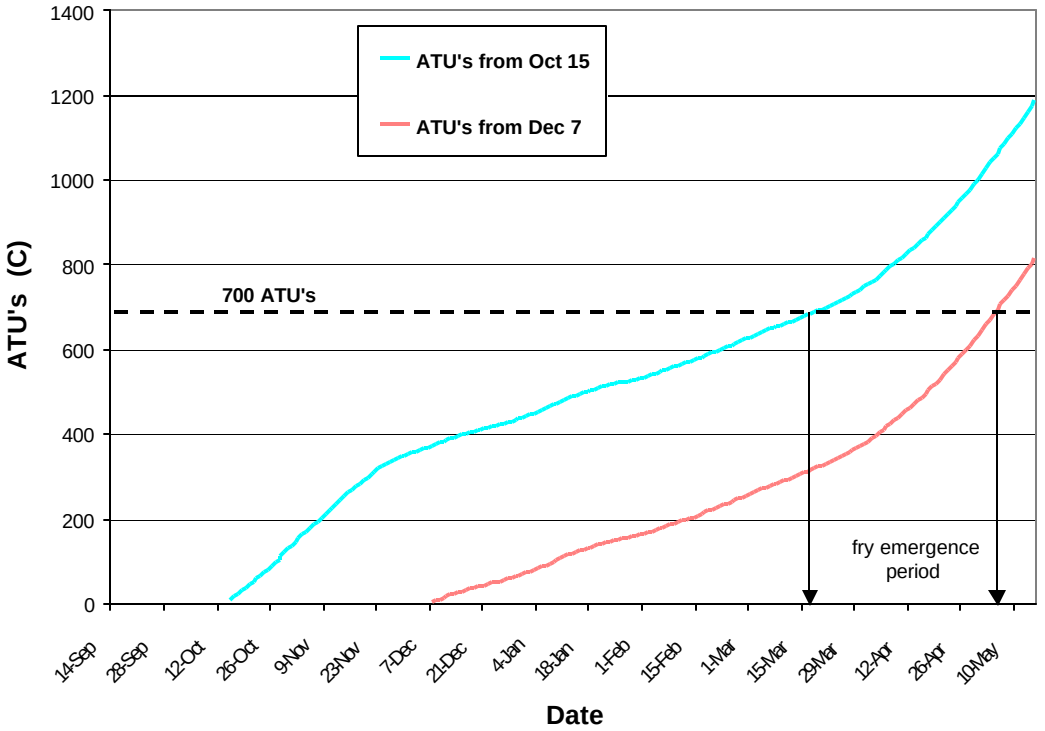
Estimated period of Dolly Varden fry emergence in Cervus Creek



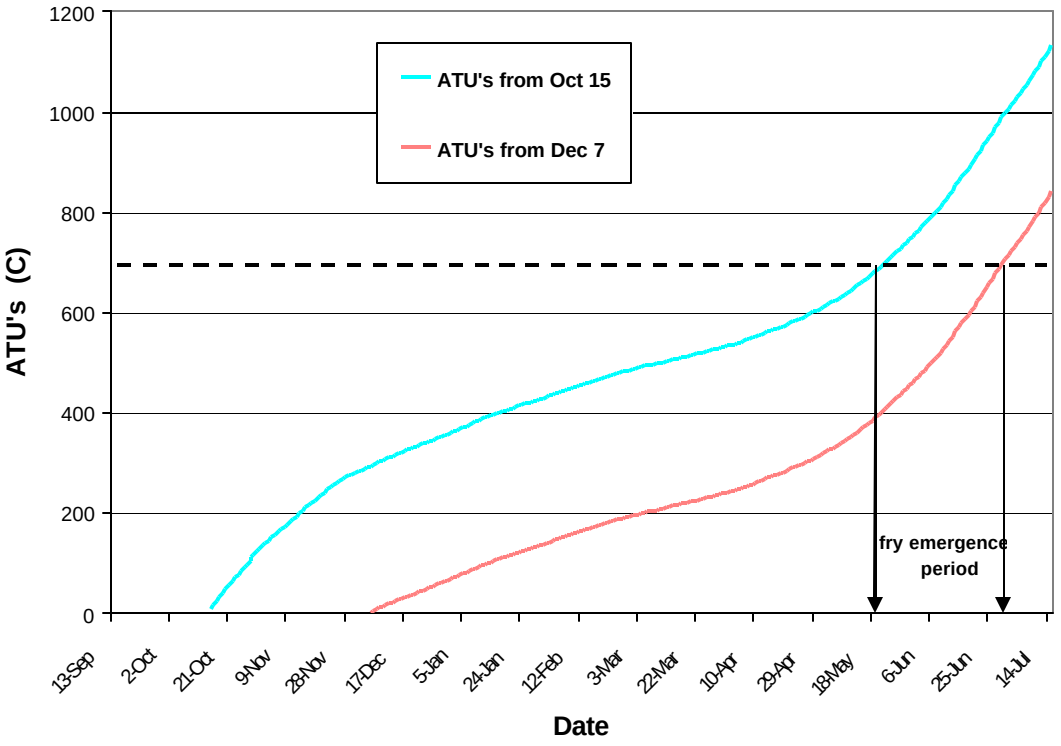
Estimated period of Dolly Varden fry emergence in the Elk River



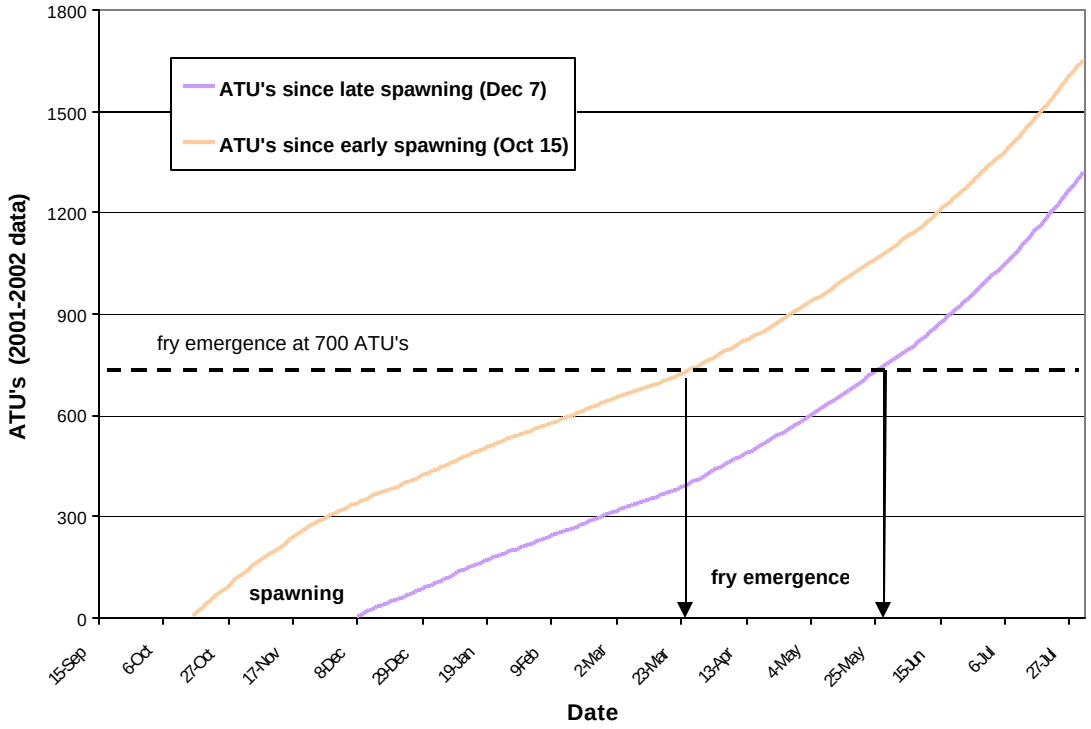
Estimated period of Dolly Varden fry emergence in Greenstone Creek



Estimated period of Dolly Varden fry emergence in Miller Creek



Estimated period of Dolly Varden fry emergence in Thelwood Creek



Estimated period of Dolly Varden fry emergence in the Cruickshank River

Appendix 4

Locations of Dolly Varden Spawning

Appendix 5

Dolly Varden Distribution in Study Area